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THE ACCUMULATION OF ENERGY BY PLANTS.*

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A century ago the chief concern of civilization was the search for new sources of materials and for more effective ways of using them. During the past quarter century the realization has been growing that our energy resources are even more important and definitely limited. Our present social and economic status has been built largely through the use of the energy of coal, petroleum and gas. The ever threatening spectre of their exhaustion has turned the attention of many toward sunlight and plants—the original source of this geologically inherited capital. Plants will always be the primary food supply. Certain optimistic engineers have also proposed to solve the future fuel problem using plants as the gatherers of the sun's energy.

It has therefore seemed profitable to study this problem of the accumulation of energy by plants both for what information it may give as to our future energy resources, and for its interest as a picture of plant metabolism from the energy point of view. Why the energetics of *plant* metabolism have seemingly lagged so far behind those of *animal* metabolism will be more apparent if we digress for a moment and look into the history of our knowledge of animal and plant metabolism.

The study of the metabolism of animals has been in progress for two and a half centuries. It had its beginning apparently in the experiments of Hooke (1667) and Mayow (1674). The latter seems to have clearly recognized the necessity of something in the air, which we now call oxygen, both for the maintenance of combustion and of vital activity in animals. Mayow's work seems to have been overlooked in the development of the

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"phlogiston theory" during the succeeding century, and in 1774 Priestley rediscovered oxygen and its importance in the metabolism of animals.

With the writings of Lavoisier (1774–1789) came more precise proof that the gas exchanges involved in combustion and in respiration are essentially the same. Lavoisier built and used the first ice calorimeter and thereby attempted to show that the heat energy liberated in the animal body is derived from the oxidations taking place in metabolism.

Seventy years later, Regnault and Reiset (1849) advanced our knowledge of these processes with definite recognition of the so-called "respiration ratio," that is, the ratio of the volume of carbon dioxide released to volume of oxygen consumed. They showed quite definitely that the value of this ratio depends upon the food consumed. It is about unity when carbohydrates are consumed and less than unity when proteins and fats are used as food.

It was not until 1892, however, that a sufficiently accurate calorimeter was constructed by Rubner to show that in metabolism the energy income and outgo also constitutes a balance. Rubner introduced the "closed system" calorimeter in which experiments could be performed with animals for several days at a time. With his equipment it was possible to determine the potential energy of the food, the amount of oxygen consumed the amount of carbon dioxide liberated, the energy released and the potential energy still present in the body wastes. In this way he was able to secure results which established that fundamental law of metabolism, that energy is neither created nor destroyed within the animal body; that the energy liberated is equal to the potential energy of the food consumed; and that the conservation of energy is just as true within the animal body as it is in the environment.

However Rubner's determinations had an error of about one per cent, and this is too large for the complete establishment of a law. The more recent experiments of Atwater and Benedict conducted both with animals and men have finally removed the last doubt about the possibility of any other sources of energy. As a result of their work we know not only the precise metabolic energy values of a great variety of foods but we have exact determinations of the energy output under a great variety of environmental conditions, with the body at rest and in action, in health and in disease. Indeed these studies have

been so enlightening that the metabolic rate has become an important method of diagnosis in medicine.

Finally, these studies of animal metabolism have established the fact that foods in addition to furnishing the material for the development and growth of the body, provide the energy to maintain bodily temperatures, for internal and external work, and for the synthesis of other substances found in the body.

The study of the metabolism of plants is a very different matter. Priestley (1774) showed that the "spoilt air" given off by animals would again support combustion and animal life if exposed to green plants in the light.

Ingenhous (1779) and De Saussure (1804) proved that plants absorb carbon dioxide and give off oxygen in sunlight and that these gas exchanges are reversed at night. De Saussure proved that the increase in dry weight of green plants occurs only when exposed to carbon dioxide. It remained for Dutrochet (1837) to show the connection between this process, which we now call photosynthesis, and the green tissues of plants and also that respiration in plants and animals is fundamentally the same.

A little later Leibig (1840) corrected the then prevalent notion that plants obtain all or a part of their carbon from the humus of the soil. But he seems to have had wholly erroneous notions of photosynthesis and respiration, and went so far as to deny that respiration comparable to that of animals occurs in plants. In spite of the excellent start toward a correct interpretation of photosynthesis and respiration, as late as 1860 the prevailing view seems to have been that plants merely exhibit two kinds of respiration, the one a diurnal and the other a nocturnal process.

All these early students of plants were denied an intelligent insight into the metabolism of plants because of their assumption from animal physiology that the food of a plant must come from the outside, a fallacy that is still being perpetuated by those who persist in speaking of "the plant food in the soil."

To Sachs (1865) belongs the honor of having first clearly stated the fundamentals of plant nutrition, and the connection between the chloroplasts and photosynthesis. Becquerel (1868) made the first attempt to determine the per cent of sunlight used by plants in photosynthesis on the basis of the plant materials produced per hectare and concluded that only about .4 of one per cent is utilized. The work of Sachs, Becquerel, and

Boussingault ushered in the modern period of our knowledge of plant metabolism.

The fact that in green plants exposed to the light photosynthesis, an energy consuming, or endothermic reaction, proceeds along with respiration, an exothermic process, complicates the study of metabolism of plants far beyond that of animals. There is seemingly no way by which the complementary gas exchanges involved in these two processes or the energy transformations can be simultaneously investigated. We can make short-time determinations of either process, and we can alternate light and darkness, and by modern methods of analysis obtain much information concerning both processes. At the same time it is clear that under these experimental conditions the relative amounts of carbohydrates and amino acids also change and with them the rate of respiration. At best we can make observations of but a few hours duration, and piece together the fragmentary determinations of energy income and outgo, and the relative rates of oxygen and carbon dioxide exchange. To complete the picture we should also be able to measure simultaneously the energy of sunlight.

It is just twenty years since Horace Brown (1905) presented to the Royal Society of London an energy budget of a green leaf.[1] This was the first attempt on an experimental basis to describe the metabolic processes of a plant organ in terms of energy income and outgo. Among other things he determined the proportion of light energy utilized by the leaf in photosynthesis, how much is absorbed, and how much passes to the environment. About the same time F. F. Blackman also published several papers that contributed to our information concerning the rates both of photosynthesis and respiration. The most notable recent contributions are those of Spohr who has corrected certain wrong impressions of the steps in these processes, and is gradually building a secure foundation for an understanding of the details of plant metabolism. But there is no probability that we shall have in the near future an experimental determination of the energy budget of a complete plant such as we have for a great variety of animals.

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[1]Brown, H. T. The Reception and Utilization of Energy by a Green Leaf. Nature, 71:522–526, 1905. See also for details Proceedings Roy. Soc. London, Series B, Vol. 76, which contains several papers by Brown, and one by F. F. Blackman.

The work of the animal physiologists, and the studies of non-green plants have shown that an energy budget can be calculated from the heat equivalents of food substances consumed and that the results so obtained are quite close to the results obtained by calorimetric experiments. Since there is no elimination of solid materials from plants, we have an advantage in that our calculations are not complicated by the energy content of these waste products.

As a result of measurements begun by Langley and continued by Abbott and his associates of the Smithsonian Institution we now have accurate determinations of the solar energy received at the earth's surface for a number of stations in the United States and these may be taken as the basis of our energy income.[2]

The chemical and physiological studies of crop plants at our Agricultural Experiment Stations have made available many data concerning dry weights, chemical composition, water requirements, and rates of respiration and growth. It ought therefore to be possible utilizing these figures to estimate the energy income, accumulation and outgo with sufficient accuracy to approximate a real energy budget for some of these plants.

Corn has been selected for this particular study because it probably represents the most efficient annual of temperature regions. It grows steadily throughout the season and forms a closed association sooner than any other of our crop plants. Moreover, there are available more data concerning corn than other crop plants.[3] Let us now examine the energy budget of a hypothetical acre of corn in the heart of the corn belt in north central Illinois where corn attains yields as great as anywhere, and not far from Madison, Wisconsin, one of the stations at which solar radiation has been studied. The growing season is from June 1 to September 8, one hundred days. The best yields have been with 10,000 plants to the acre. One hundred bushels, with a dry weight of 2160 kg. per acre, is the yield assumed

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[2]Kimball, H. H. Variations in the Total and Luminous Solar Radiation with Geographical Position in the United States. Monthly Weather Review, 47:769–793, November, 1919.

[3]Vivian, Alfred. First Principles of Soil Fertility, pp. 9–11. 1908.

Latshaw and Miller. Elemental Composition of the Corn Plant. Jour. Agr. Research, 27:845–859. 1924.

Briggs and Shantz. The Water Requirements of Plants. Bur. Plant Indus. Bull. 284 and 285. 1913.

Briggs and Shantz. Relative Water Requirements of Plants. Jour. Agric. Research, 3:1–63. 1914.

Kisselbach, T. A. Transpiration as a factor in Crop Production. Nebraska Agric. Exper. Sta. Tech. Bul. 6:1–214. 1915.

although it is not a maximum crop for the corn belt. How well an acre of corn covers the area is shown by the fact that during the latter half of the season nearly two acres of leaves are exposed to the light.

TABLE 1. AVERAGE ELEMENTAL COMPOSITION OF THE CORN PLANT.

Corn Plant	Water 79.7%			
	Dry matter 20.3%	Organic matter 19.5%	Carbohydrates	12.2
			Fiber	5.0
			Fat	0.5
			Protein	1.8
		Mineral Elements 0.8%	C — 44.58	
			O — 43.79	
			H — 6.26	
			N — 1.43	
			K — 1.62	
			P — .25	
			Ca — .59	
			Mg — .44	
			Fe — .10	
			S — .05	
			Cl — .20	
			Na — .15	
			Si — .54	

At maturity the average corn plant contains about 20 per cent of dry matter and about 80 per cent of water. (Table 1.) Of the dry matter, carbon makes up about 44.58 per cent. This is the most important figure for our calculations derived from the chemical analyses of the corn plants. We must also know the total amounts of mineral elements present which is 5.37 per cent from which we can derive the fact that 94.63 per cent of the plant's dry weight is organic matter. The dry weight of an average corn plant growing under these circumstances is 600 g., of which 216 g. makes up the grain 200 g. the stalk, 140 g. the leaves, and 44 g. the roots. The total weight of the 10,000 plants is 6000 kg. Subtracting from this the 322 kg. of mineral elements in the ash we have left 5678 kg. of organic matter, of which 2675 kg. is carbon.

TABLE 2. GLUCOSE EQUIVALENT OF ACCUMULATED CARBON.

Dry weight of ave. plant 600g	grain	216
	stalk	200
	leaves	140
	roots	44
Total dry wt. of 10,000 plants		=6000 kg.
Total ash (5.37% of dry weight)		= 322 kg.
Total organic matter of acre		=5678 kg.
Total carbon accumulated (44.58%)		=2675 kg.
Glucose equivalent of accumulated carbon		=6687 kg.

$C_6H_{12}O_6 : C_6 = 180 : 72$

To estimate the amount of photosynthesis we must determine the amount of carbon, because carbon enters the plant only by photosynthetic reduction of CO_2. The total carbon is 2675 Kilograms and the glucose equivalent of this carbon is 6687 kilograms. This is the amount of primary sugar equivalent to the carbon accumulated in the mature plant. (Table 2).

TABLE 3. GLUCOSE EQUIVALENT OF RESPIRATION.

Estimated rate of CO_2 release = 1% of the dry wt per day	
Average dry weight for season ($\frac{1}{2}$ total wt.)	= 3000 kg.
Average rate of CO_2 release (.01 × 3200) per day	= 30 kg.
Total CO_2 release during season	= 3000 kg.
Carbon equivalent: $C : CO_2 = 12 : 44$	= 818 kg.
Glucose equivalent $C_6H_{12}O_6 : C_6 = 180 : 72$	= 2045 kg.

At maturity however, only a part of the carbon remains, for some has been lost as CO_2 in respiration (Table 3). The average rate of CO_2 loss is not far from one per cent of the dry weight per day. This would cause a daily loss of 30 kilograms of CO_2, and during the entire season a loss of 3000 kilograms. The glucose equivalent to this amount of carbon dioxide is 2045 kilograms.

Adding the amount of this lost glucose to the glucose equivalent of the carbon in the plant, gives the total glucose manufactured as 8732 kilograms. It requires energy equivalent to 3760 calories to produce one kilogram of glucose. Hence it required not far from 33 million calories to produce the entire photosynthetic product. (Table 4).

TABLE 4. ENERGY CONSUMED IN PHOTOSYNTHESIS.

Glucose equivalent of accumulated carbon	6687 kg.
Glucose equivalent of carbon oxidized	2045 kg.
Total glucose manufactured	8732 kg.
Energy required to produce 1 kg. glucose	3760 Cal.
Total energy consumed in photosynthesis	33 million Cal.

We are now in a position to estimate the efficiency of the corn plant as a photosynthetic agent: (Table 5).

TABLE 5. EFFICIENCY OF PHOTOSYNTHESIS.

Total energy available on acre during the growing season	2043 million Cal.
Total energy used in photosynthesis	33 million Cal.
Per cent of available energy used by the corn plant in photosynthesis, (efficiency of corn plant)	1.6%
Of the total light spectrum measured, however, only about 20% is used in photosynthesis, hence the efficiency of the photosynthetic process is	8%

The total energy available according to the Smithsonian figures is 2043 million Calories. The energy utilized is 33 million,

or 1.6 per cent. In photosynthesis however, only certain rays are effective, and these furnish about 20 per cent of the energy measured by the pyrheliometer.[4] Consequently the efficiency of photosynthesis in 100-bushel corn is 8 per cent.

Another source of energy loss to the plant is transpiration. From the water requirement studies of corn it is probable that in Illinois not far from 276 kilograms of water are evaporated during the growing season for every kilogram of its dry weight. (Table 6). The total weight of water lost in this way therefore is one and a half million kilograms. This is equal to 408,000 gallons or sufficient water to cover the acre to a depth of fifteen inches.

TABLE 6. ENERGY CONSUMED IN TRANSPIRATION.

Total dry weight of the aerial parts	5560 kg.
Estimated rate of water transpired per kg. of dry matter per season	276 kg.
Total water transpired by the acre	1.5 million kg.
Energy required to evaporate 1 kg. water at the average temperature of growing season	593 Cal.
Total energy consumed in transpiration (593 × 1,534,560) = 910 million Cal.	
Of the available energy (2043 million Cal.) transpiration consumed about 44.5%	

The energy necessary to evaporate one kilogram of water at the average temperature of the growing season is 593 calories. Consequently 910 million Calories are expended in this way. This is equivalent to 44.5 per cent of the available energy.

TABLE 7. ENERGY RELEASED IN RESPIRATION.

Glucose consumed in respiration	2045 kg.
One kilogram of glucose releases	3760 Cal.
Total energy released in Respiration	7.7 million Cal.
Of the energy made potential in photosynthesis, Respiration releases	23.4%
Assuming that photosynthesis goes on 12 hours each day and respiration 24 hours each day, the average daily rate of photosynthesis is about 8 times the rate of respiration.	

Respiration again releases a part of the energy rendered potential in photosynthesis. As we have seen 2045 kilograms of glucose are thus oxidized, and in consequence 7.7 million

[4]For the region of north central Illinois Professor Abbot estimates that the proportion of total energy contained among the rays utilized in photosynthesis is as follows:

Wave-length limits	Air Mass 2	Air Mass 3
670–635μ	4.6%	4.5%
622–597μ	3.4	3.1
587–565μ	3.0	2.7
544–530μ	1.9	1.7
495–420μ	9.0	7.3
Total	21.9%	19.3%

Calories are released within the plant. This energy raises the temperature of the plant and escapes to the environment, or it is used in synthesis of fats, proteins and other reduced organic substances.

The energy released in respiration amounts to 23.4 per cent—almost one-fourth of the energy absorbed in photosynthesis. This is far more than is needed to account for the endothermic reactions associated with food transformations within the plant.

Assuming that photosynthesis goes on 12 hours and respiration 24 hours each day, the average rate of photosynthesis must be about 8 times the rate of respiration.

TABLE 8. SUMMARY OF BUDGET.

Total energy available	2043 million Cal.
Used in photosynthesis	33 million Cal.
Used in transpiration	910 million Cal.
Total energy consumed	943 million Cal.
Energy not directly used by the plants	1100 million Cal.
Energy released by respiration	8 million Cal.
Of the available energy, 100-bushel-corn uses about	46%
The environment takes up about	54%

We may now summarize the energy budget. The total income is 2043 million Calories. The expenditure for photosynthesis and transpiration is 943 million Calories. Respiration returns 8 million Calories. Therefore the plant uses about 46 per cent, and the environment takes up 54 per cent. As a result we are in a position to make a number of generalizations regarding the metabolism and growth of plants, both as to materials and energy.

1. An acre of 100-bushel corn uses during the growing season about 408,000 gallons of water or 15 acre-inches.

2. The evaporation of this water consumes about 45 per cent of the available light energy.

3. In photosynthesis the corn plant utilizes about 1.6 per cent of the energy available; its efficiency is about 8 per cent.

4. An acre of 100-bushel corn manufactures on the average 200 pounds of sugar a day.

5. Of the energy rendered potential in photosynthesis, 23.4 per cent is again released in respiration.

6. Of the sugar manufactured nearly one-fourth is oxidized in respiration.

7. Respiration releases several times as much energy as is needed to account for the reductions in the synthesis of fats, proteins and other compounds.

8. At maturity the grain contains about one-fourth of the total energy utilized in photosynthesis, or about .5 per cent of the energy available.

9. The average rate of photosynthesis is about eight times the rate of respiration.

10. Since the young corn seedling weighs .3 grams and the mature plant wighes 600 grams, on the basis of the compound interest law of growth the average daily increment in dry weight is 7.9 per cent.

Returning now to the questions proposed in the introduction to this paper regarding future food and fuel supplies. If corn is the most efficient of our temperate zone corn plants, and if 100-bushel corn can utilize only 1.6 per cent of the available energy, it must be apparent that the average crop plant falls far below this amount. It is evident also that we can never expect many of our other crop plants in temperate regions to equal this production, and we must agree that plants are very inefficient gatherers of energy.

The suggestion that our liquid fuels, petroleum and gasolene, may some day be replaced by alcohol made from plants is quite unreasonable. A little figuring will show that to substitute the energy of alcohol for the energy now being developed from gasolene would require all the corn now being grown in the United States.

The solution of our future fuel energy supplies lies rather in the discovery of the physics and chemistry of photosynthesis. We have in the past discovered the nature of many biological processes.

It is not so many years ago since it was thought that only plants and animals could synthesize organic compounds. Now we can make hundreds of them more efficiently than either plants or animals. There is no good reason to think that photosynthesis is impossible of explanation and imitation. Photosynthesis is a very inefficient process, but when we once know its photo-chemical basis we should be able to improve on it greatly and herein lies the best hope of future supplies of energy, almost unlimited and certainly inexhaustible.

THE ALIMENTARY CANAL OF PASSALUS*

HAROLD C. LEWIS

Introduction

It has long been known that the alimentary canal of *Passalus cornutus* Fab. harbors an extensive associated flora and fauna. Also, its sub-social habits have attracted some attention. Because of this and its specialized food habits *Passalus* offers an interesting problem in tracing the results of such specialization upon the digestive canal. This paper is not intended as a final and complete work, but more as a preliminary discussion dealing especially with the morphology of the alimentary tract.

The writer wishes to express his appreciation to Mr. A. A. Mathewson, who did half of the work in the preparation of the slides and then accepted a position precluding further study, and to Dr. C. H. Kennedy, under whose direct supervision this work has been carried on.

Leidy (1851) first called attention to the flora and fauna in the hind intestine of *Passalus cornutus*. He gives a short description of the alimentary tract using a slightly different terminology from that generally used at present. Considering the attachment of the Malpighian tubules as a landmark in setting off the hind-intestine from the mid-intestine, the proventriculus as used by Leidy consists of the fore-intestine and the mid-intestine, which includes the ventriculus or true-stomach. The ventriculus as used by Leidy is a part of the hind-intestine, since it is set off from the mid-intestine by the attachment of the Malpighian tubules and is lined with a chitinous intima. This part of the hind intestine is here considered as the ileum and harbors the extensive flora and fauna as described by Leidy. The flora of fungi is limited to the distal portion of the ileum, which is characterized by numerous sacculi or folds of the intestinal wall.

In all the beetles examined, these fungus gardens were present and it seems that their occurrence is regular in the specialized ileum of *Passalus cornutus*. Mr. R. H. Painter, of this department, has successfully cultured two of these fungi.

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* Contribution from the Department of Zoology and Entomology, Ohio State University, Number 83.

Leidy describes several fungi, *Enterobryus attènuatus*, *Arthromitus cristatus*, *Cladophytum comatum*, and *Corynocladus radiatus*, as being fixed parasitic on the mucous membrane of the intestine. He also describes an elongated tubular cellule and a granulo-filamentous phytoid substance as parasitic phytoid bodies, the exact nature of which he was uncertain, and several pseudo-entophyta. *Gregarina Passalicornuti* and *Hystrignathus rigidus* are listed as being associated with the flora of the intestinal canal.

The relation of many insects to micro-organisms has occupied the attention of a few investigators. It has been shown in some cases, Baumberger (1919), that micro-organisms furnish food for the insects. In others the organisms exist as parasites, while in some a symbiotic relationship occurs, as Cleveland (1924) has proved to be the case with termites. Leidy considers these organisms as being parasitic within the alimentary tract of *Passalus*. However, their regular occurrence and the specialized food habits of the beetle suggests the possibility that this may not necessarily be so. Some of these intestinal fungi may play an important part in the physiology of digestion. Further work on the digestion and the embryology of the alimentary tract seems to be necessary to clear up this relationship. Leidy pointed out that the millipede, *Julus marginatus*, which also lives on decaying and rotting wood, has an extensive floral and faunal association.

The Gross Anatomy of the Adult Canal.

The alimentary canal of the adult beetle shows considerable specialization in form and structure. In accordance with the general rule that in herbiverous insects the alimentary tract is longer than in carniverous insects, in *Passalus* it is a winding convoluted tube about three times as long as the body. The canal makes three complete loops and turns back on itself twice. Three chief divisions of the tract are readily recognized, which are the fore-intestine (stomodeum), the mid-intestine (mesenteron or ventriculus), and the hind intestine (proctodeum). The general form of the gross anatomy is shown in Fig. 1.

The fore-intestine is a straight, comparatively short tube extending from the mouth to about the beginning of the meso thorax. The pharynx is evident as a slight dilation of the trac in the head. The oesophagus is a slender elongate tube, extend-

ing into the prothorax, where it gradually enlarges to form the crop. The mid-intestine is separated from the fore-intestine by a constriction composed of two distinct rings.

The mid-intestine is a long coiled tube making three complete loops. It is almost uniform throughout and excepting the posterior tip is covered by numerous small papillae, which are crypts or diverticula of the digestive epithelium. These give it a white maculated appearance.

The hind-intestine, which is somewhat shorter in length than the mid-intestine, is divided into four regions. Poyarkoff (1910) recognized four parts in the hind intestine of a Chrysomelid, *Gallerucella luteola*, according to Wood (1916). There are four distinct divisions of the hind intestine of *Passalus* which are considered as the proximal portion of the ileum, the distal portion of the ileum, the colon, and the rectum. The first region, the proximal portion of the ileum, is comparatively short and appears much the same as the mid-intestine, except that it is not covered by papillæ. The distal portion of the ileum is much larger and longer and is characterized by numerous large folds of the intestinal wall. It is in these folds that the intestinal fungi live. This part of the ileum extends almost directly caudad for over half of its length and then turns cephalad. The colon is a long, slender tube forming a large semicircle on top of the coiled ventriculus, straightening out towards the tip of the abdomen. The rectum is short, but is evident as a slight enlargement of the tract somewhat lighter in color than the colon.

For a discussion of the mouthparts and skeletal elements, see Landacre (1902).

The succeeding discussion of the histological structure of the alimentary canal is taken up in order, beginning at the anterior end.

The Histological Structure of the Fore-Intestine.

Pharynx.—In *Passalus* this region is evident as a slight enlargement of the tract with a heavy chitinous lining continuous with that of the body wall. The primary intima is covered with fine chitinous spines which project caudad. The secondary intima appears slightly fibrillar, almost transparent, and is much thicker than the primary intima. The epithelium consists of a definite layer of small irregular cells. The muscle layers are much the same as in the oesophagus.

Oesophagus.—The intima of the oesophagus is thrown into a series of longitudinal folds (Fig. 2). These are irregular and usually are six in number. The primary intima is well developed and is covered by numerous spines of varying lengths. The secondary intima is much thicker and is almost transparent. (Fig. 3).

The epithelium of the oesophagus consists of irregular cuboidal cells. The basement membrane is present.

The longitudinal muscles form a layer covering the epithelium. They do not all run directly longitudinally, but intertwine considerably, so that cross-sections of this region show many of them running in an oblique fashion. All sections made show that the space between the epithelium and circular muscular layer is not completely filled by these longitudinal muscles.

The circular muscles form a layer covering the longitudinal muscles. This layer varies somewhat in thickness and forms a complete covering around the tract.

Crop.—In the crop the lumen is wider than in the oesophagus, the epithelium is thinner, and the chitinous folds are much smaller.

The primary intima is thin and lacks the chitinous teeth of the oesophagus. The secondary intima is much thicker and is almost transparent.

The epithelial cells of the crop are much like those of the oesophagus, except that in places instead of being cuboidal they are flattened. In some of them appear irregular sphere-like bodies, somewhat larger than the nuclei and which stain black with Delafield's haemotoxylin and eosin. The identity and nature of these Rickettsia-like bodies is undetermined. They are found only in the crop and in that portion of the fore-intestine forming the fold of the oesophageal valve. The basement membrane is well defined.

The longitudinal muscles are much less in evidence than in the oesophagus. Anteriorly they continue into the oesophagus and posteriorly end in the fold of the oesophageal valve. (Fig. 11).

The circular muscles are more in evidence than the longitudinal muscles. They form a complete layer around the canal much the same as in the oesophagus.

Oesophageal Valve.—In the transition from the fore-intestine to the mid-intestine, the fold of tissue composing the oesophageal

valve is well developed (Fig. 11). The structure of the wall of the fold is much like that of the wall of the crop. Intima, epithelium, basement membrane, longitudinal and circular muscle layers are present. The intima ends gradually, in longitudinal section, coming to a point on the posterior face of the valve.

The intima disappears on the posterior face of the fold which marks the limits of the fore-intestine.

The epithelial cells of the anterior face of the oesophageal valve continue much the same as in the crop until just before reaching the tip of the fold. Here the cells begin to elongate and become gradually longer on the posterior face of the valve until the end of the fore-intestine is reached. At this point a ring of spindle-shaped cells is encountered, which terminates the epithelium of the fore-intestine. The turgid appearing digestive epithelial cells follow immediately after this ring of spindle-shaped cells.

The exact nature of this ring of spindle-shaped cells is undetermined. It marks the limits of the fore-intestine and possibly may be the imaginal disc of some authors. The nuclei of these spindle-shaped cells contain almost no deep-staining chromatin material, whereas, the nuclei of both the epithelial digestive cells of the stomach and the epithelial cells of the fore-intestine contain much deep staining material. The basement membrane is continuous from the fore-intestine to the mid-intestine.

The longitudinal muscles of the fore-intestine end near the tip of the anterior face of the oesophageal valve. In the tip of the fold there are no muscles whatever. On the posterior face of the fold the longitudinal muscles of the mid-intestine begin. They are fewer in number and smaller than those of the fore-intestine.

The circular muscles of the fore-intestine end at about the middle of the anterior face of the oesophageal valve. At this point they are much smaller in size than the longitudinal muscles. The circular muscles of the mid-intestine appear soon after the longitudinal muscles of the mid-intestine begin. They are small isolated strands.

The peritoneal membrane is not concerned in the fold of the valve, but is continuous from the fore-intestine to the mid-intestine. Along with it run several fibers of longitudinal muscle.

The Mid-Intestine.

The mid-intestine or ventriculus is an elongate tube, a little longer than the body of the insect itself, and is almost uniform throughout, (Fig. 1). It is characterized principally by the numerous crypts or diverticula of the stomach wall, by the absence of a chitinous intima, and by the presence of large secretive epithelial cells, (Fig. 4).

Peritropic Membrane.—In the ventriculus of *Passalus* the secretion of digestive fluids by the epithelial cells forms a granular layer. Its inner border usually forms, as shown by cross-sections, a distinct dark staining line known as the peritropic membrane. In places it can be seen that the entire mass separates from the epithelial cells. The usual explanation given is that this process continues indefinitely and the peritropic membrane shrinks around the food in the lumen of the gut, while new membranes are repeatedly being formed by the discharging epithelial cells. The peritropic membrane extends from the oesophageal valve at the anterior end of the ventriculus into the hind-intestine to about the middle of the proximal portion of the ileum.

The epithelium of the ventriculus forms the layer of cells whose function it is to secrete the digestive fluids into the lumen of the gut. In *Passalus* we find a very specialized condition for, apparently, secretion is both holocrine and merocrine. It is holocrine in the epithelium of the central canal and merocrine in the epithelial cells at the bottom of the crypts.

Commonly the wall of the ventriculus of beetles is evaginated to form crypts or diverticula which increase the digestive surface. This holds true in *Passalus* and a single cross-section near the center of the ventriculus shows about sixty of these crypts, (Fig. 4). At the bottom of each crypt are broad epithelial cells, each connected to a common opening by a short canal. Each canal is lined by a dense layer of dark staining substance which is known as the *striated border*. As pointed out above, the type of secretion from these epithelial cells is merocrine.

In the neck of each crypt the epithelial cells are of a different nature, being elongate and turgid appearing. This type of cell completely lines the central canal of the ventriculus. Secretion is holocrine, that is, the entire cell contents are discharged into the lumen of the gut, and the discharged cells are replaced from embryonic nests of "nidi."

From a few of the crypts in the wall of the ventriculus are gland-like appearing evaginations. They are densely filled with dark staining nuclei. The nature and function of these nuclear crypts is undetermined, (Fig. 5). The basement membrane of the ventriculus is present.

The circular muscles form two distinct layers. The first is very thin and is composed of fibers circling the central tract of the ventriculus, but they do not extend over the crypts. They frequently run obliquely and cross each other in an irregular manner. The second layer of circular muscles forms a thin incomplete layer on top of the crypts in a twisted fashion.

The longitudinal muscles of the ventriculus are small and isolated among the fibers of the second layer of circular muscles.

The wall of the crypts apparently contains no muscular layers, but is covered by a peritoneal membrane of connective tissue.

The Transition from the Mid-Intestine to the Hind-Intestine.

The hind-intestine is set aside from the mid-intestine by a fold of tissue called the pyloric valve. In *Passalus* this is not a true valve in the sense that it closes the tract at this point, but it is a fold of tissue marking the transition from the mid-intestine to the hind-intestine. The size of this fold is so small in comparison to the width of the tract at this point that it could have little significance as a valve in closing the tract. However, since there are two distinct folds, one immediately following the other, it is here considered as the pyloric valve.

The Pyloric Valve.—Sections from several different beetles showed the form of the folds to vary considerably, but the anterior fold is always much smaller than the posterior one. The intima first appears at the beginning of the anterior fold and is smooth over the entire valve. The epithelial cells are elongate and regular. Fibers of longitudinal muscles extend into the folds, (Fig. 7).

The peritropic membrane is continuous from the mid-intestine into the proximal portion of the ileum.

The intima of the hind-intestine appears on the anterior fold of the valve and both primary and secondary intima are clearly evident. The primary intima is smooth over the folds of the valve, but in the ileum is covered by posteriorly projecting spines.

The epithelium is continuous from the mid-intestine to the hind-intestine. The digestive epithelial cells cease abruptly at the point of the beginning of the first fold of the valve and the point where the intima of the hind-intestine begins. In the valve the cells appear elongate and regular, whereas in the ileum they are cuboidal and irregular. The basement membrane is continuous from the mid-intestine to the hind-intestine.

The circular muscles appear as being continuous from the mid-intestine to the hind-intestine. With the beginning of the valve there appears an additional set of circular muscles lying between the epithelium and the longitudinal muscles. Thus in this region there appears three layers of muscles which are: a layer of inner large circular muscles, a layer of longitudinal muscles and a layer of outer smaller circular muscles occurring as isolated strands in the longitudinal layer.

The longitudinal muscles appear as a thin continuous layer from the mid-intestine to the hind-intestine. Fibers extend into the folds of the valve.

The Hind-Intestine

The first division of the hind-intestine may be divided morphologically into two parts, the proximal and distal portions of the ileum. The proximal portion extends from the beginning of the hind intestine to the beginning of the intestinal coecom. The distal region composes the remainder of the ileum and is characterized by large folds in the wall which harbor the intestinal fungi, (Fig. 1).

The Proximal Portion of the Ileum.—The primary intima is evident from the beginning of the folds of the pyloric valve. It is smooth over the valve and then gradually becomes roughened so that posteriorly projecting teeth are developed. The secondary intima is much thicker than the primary intima, is almost transparent, and shows little difference in the two divisions of the ileum.

The epithelial cells are cuboidal and irregular. The basement membrane is clearly evident.

The circular muscles of the proximal portion of the ileum are largely confined to a layer between the epithelium and the incomplete layer of longitudinal muscles. The layer becomes gradually thicker towards the distal portion of the ileum. The muscles are much larger than those of the mid-intestine, (Fig. 7).

The longitudinal muscles are evident as a thin incomplete layer on top of the circular muscles. These disappear entirely at about the point of the beginning of the intestinal coecum.

The Distal Portion of the Ileum.—The wall of this part of the ileum is folded to form six series of about twenty chambers, (Fig. 10). It is in these chambers that the intestinal fungi are found, though a few are wound around the spines found throughout this region of the ileum. The particles of chewed up wood are mainly confined to the central canal and are not found in the bottoms of the chambers.

The intima is covered by numerous long sharp spines, except in the bottoms of the chambers. Here the intima is merely roughened. The secondary intima is much the same throughout and appears slightly granular and almost transparent, (Fig. 12).

The epithelial cells are irregular, cuboidal, and about the same thickness as the secondary intima. A basement membrane is present.

A layer of circular muscles covers the epithelial cells and forms a complete layer several strands in thickness.

Longitudinal muscles are absent in the distal portion of the ileum.

The intestinal coecum is an enlargement of one of the intestinal folds characteristic of the distal portion of the ileum, (Fig. 1). In histological structure it is the same as that of the distal portion of the ileum.

Transition from Ileum to Colon.

In the region of the transition from the ileum to the colon there is a fold in the wall of the tract which is considered as the intestinal valve, (Fig. 8). In all of the beetles sectioned, the fold was always retracted and whether it can be extended to close the tract at this point was not determined.

The intima in the fold is smooth and lacks the chitinous spines which cover the intima of the main tract. Otherwise there is no difference in the intima, epithelium, and basement membrane which are concerned in the fold. The spines gradually become shorter and disappear entirely a short distance past the valve. Over the fold there are no circular muscles which are characteristic of this region, but instead there is a heavy layer of longitudinal muscles.

The epithelial cells are much the same as in the ileum, except that they gradually become larger and at the point where the circular muscles disappear become more regular and elongate.

The layer of circular muscles becomes smaller and disappears entirely a short distance past the intestinal valve. The epithelium at this point is covered only by a peritoneal membrane.

Colon.—The intima in the colon is smooth and somewhat thinner than in the ileum. The primary intima is a thin dark staining layer, while the secondary intima is a thicker and almost transparent layer, (Fig. 6).

The epithelial cells are comparatively regular and elongate. Through most of the colon the wall of the tract is largely epithelium. Towards the distal end the cells become larger, more elongate, and more regular. Nuclei show clearly throughout. At the distal end the wall of the tract is thrown up into six divisions corresponding to the six divisions of the muscles of the colon, (Fig. 9). A basement membrane is present.

Circular muscles are not present in the colon.

Longitudinal muscles are not present at the beginning of the colon, but appear later. They gradually become larger and larger, forming an almost complete covering around the tract. They disappear entirely at the end of the colon.

Rectum.—The intima of the rectum is thrown into six folds which at one point almost close the lumen of the gut. The intima is distinct and slightly roughened, but not covered by spines, (Fig. 13).

The epithelial cells are irregular and cuboidal and pile up on each other in the folds. The nuclei are clear and distinct. The cells are several times smaller than the epithelial cells of the colon.

The circular muscles of the rectum appear as a distinct thick layer. The change from the colon to the rectum is very abrupt. The longitudinal muscles disappear and there arises immediately a heavy layer of circular muscles, (Fig. 14). In a short distance the musculature reaches its greatest development and gradually tapers off to the anus. The muscles are divided into six regions by six radial connective tissue (?) septa, (Fig. 13).

Longitudinal muscles are absent in the rectum.

Malpighian Tubules.

In the adult beetle there are four Malpighian tubules which are long and thread-like. Each is attached to the alimentary canal at a single place which is at the point of transition from the mid- to the hind-intestine. The two dorsal tubes are evident in a dorsal dissection passing caudad and disappearing under a fold of the stomach. The two ventral tubes pass under the same fold of the stomach and the four tubes come in contact with the colon at about half way from the ileum to the rectum. They appear on the colon as a maze of convoluted tubes and eventually two of them extend along the posterior portion of the colon where they end blindly in the body cavity attached to tracheae. The other two tubes extend forward and cross to the stomach, forming a mass of convoluted tubes. They extend along the anterior portion of the stomach, where they end blindly in the body cavity.

Histologically the layers of the wall in the Malpighian tubules are the same as in the rest of the hind-intestine. The intima is very thin and irregular. The epithelium consists of irregular cuboidal cells which constitute the greater part of the wall. A basement membrane is present and the muscular layers are absent.

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EXPLANATION OF PLATES.

Plate I.

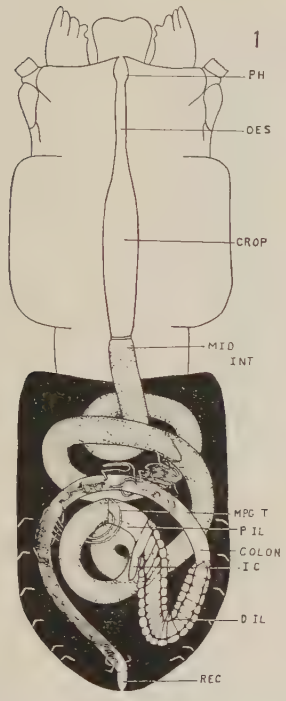
Fig. 1. Dorsal view of adult *Passalus* showing alimentary canal.
Fig. 2. Cross-section of Oesophagus.
Fig. 3. Section "A" of Fig. 2 enlarged.
Fig. 4. Cross-section through central part of mid-intestine.
Fig. 5. Section "B" of Fig. 4 enlarged.

Plate II.

Fig. 6. Section "C" of Fig. 9 enlarged.
Fig. 7. Longitudinal section through pyloric valve.
Fig. 8. Longitudinal section through intestinal valve.
Fig. 9. Cross-section of colon near posterior end.
Fig. 10. Cross-section of distal portion of ileum.
Fig. 11. Longitudinal section of oesophageal valve.
Fig. 12. Section "D" of Fig. 10 enlarged.
Fig. 13. Cross-section of rectum.
Fig. 14. Section "E" of Fig. 13 enlarged.

ABBREVIATIONS USED IN THE FIGURES.

PH—Pharynx
OES—Oesophagus
MID INT—Mid-intestine
MPG T—Malpighian tubules
P IL—Proximal ileum
I C—Intestinal coecum
D IL—Distal ileum
REC—Rectum
C M—Circular muscle
L M—Longitudinal muscle
E—Epithelium
S I—Secondary intima
P I—Primary intima
MUS—Muscle
PTR M—Peritropic membrane
PTN M—Peritoneal membrane
S B—Striated border
N C—Nuclear crypt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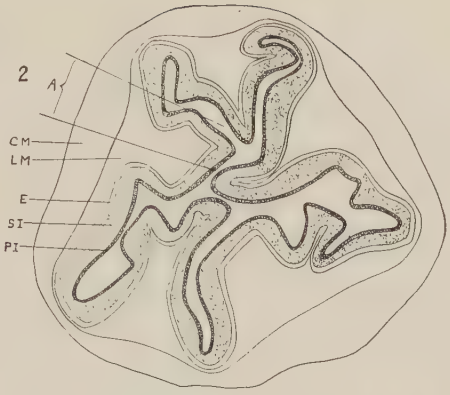
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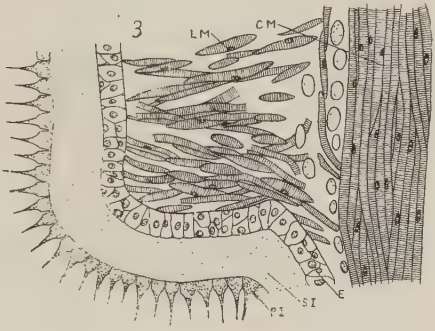
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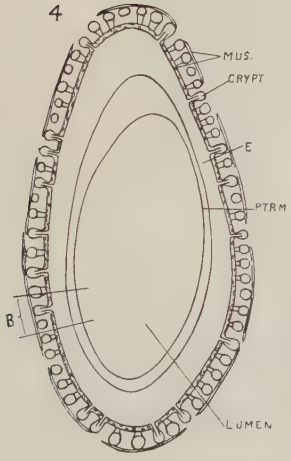
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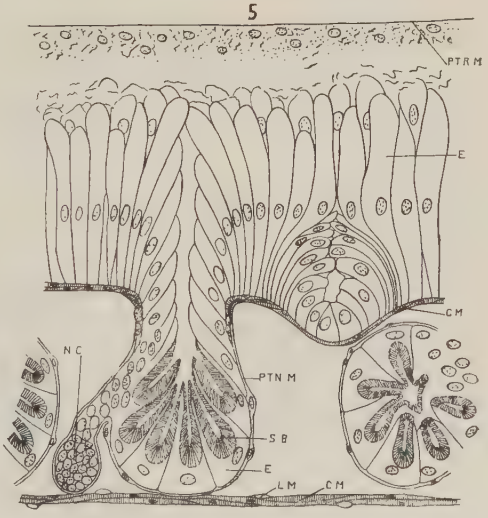
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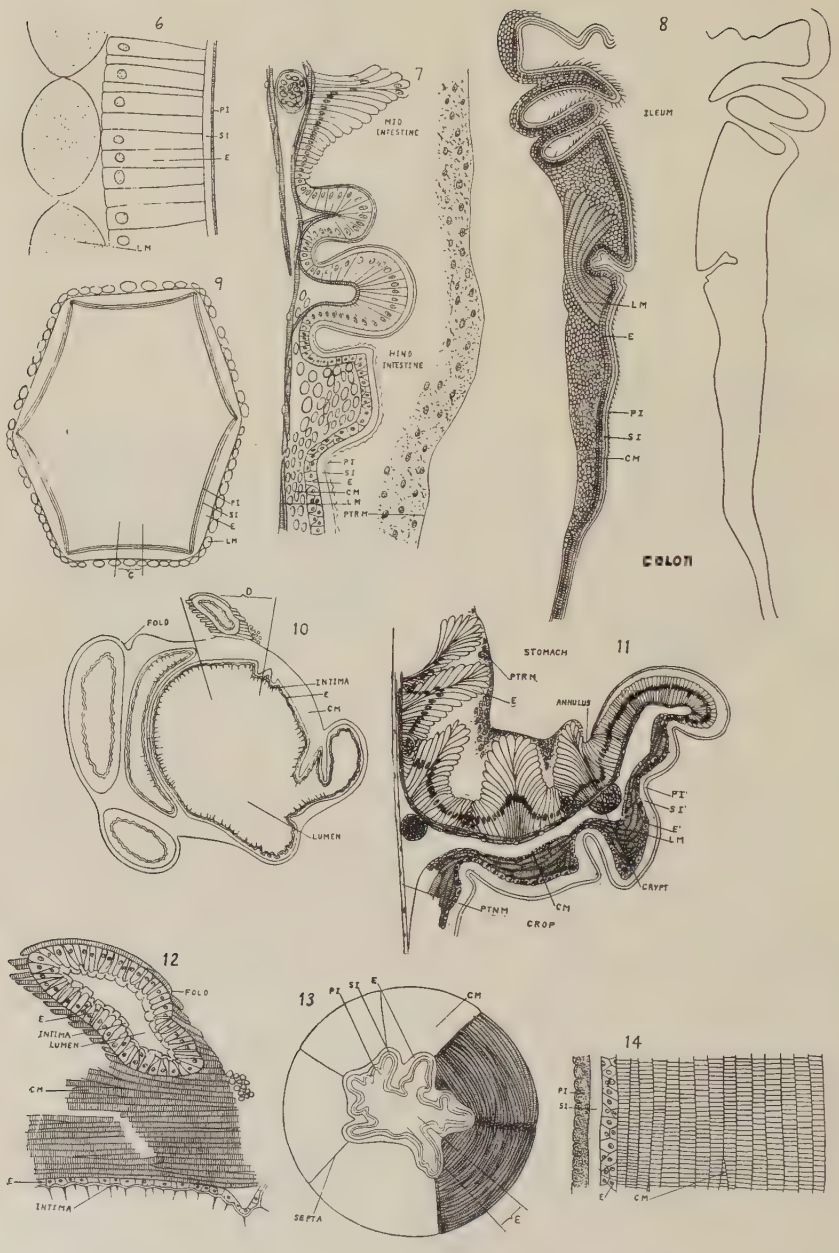
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GLASS SANDS OF OHIO

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AGE OF GLASS SAND ROCKS.

The sands of Ohio that have been used for glass making or are now so used range in age from the Devonian to the Pennsylvanian. The following section shows more definitely the principal horizons:

Pennsylvanian system	Allegheny formation Pottsville formation
Mississippian system	Logan formation Black Hand formation
Devonian system	Sylvania sandstone

SPECIFICATIONS FOR GLASS SANDS.

The American Ceramic Society has tentatively set specifications for glass sand, and while these include a number of items the most important by far is the chemical composition. The specifications on this point follow:*

PERCENTAGE COMPOSITION OF SANDS OF VARIOUS QUALITIES (BASED ON IGNITED SAMPLES).

QUALITIES	SiO_2 Min.	Al_2O_3 Max.	Fe_2O_3 Max.	CaO MgO Max.
First quality optical glass	99.8	0.1	.02	0.1
Second quality flint glass containers tableware	98.5	0.5	.035	0.2
Third quality flint glass	95.0	4.0	.035	0.5
Fourth quality sheet glass rolled and polished plate	98.5	0.5	.06	0.5
Fifth quality sheet glass rolled and polished plate	95.0	4.0	.06	0.5
Sixth quality green glass containers and window glass	98.0	0.5	0.3	0.5
Seventh quality green glass	95.0	4.0	0.3	0.5
Eighth quality amber glass containers	98.0	0.5	1.0	0.5
Ninth quality amber	95.0	4.0	1.0	0.5

*Am. Cer. Soc., Vol. 6, No. 6, p. 182.

PRODUCTION OF GLASS SAND IN OHIO FOR CERTAIN YEARS.

	Short Tons	Value
1902	42,311	$ 50,426
1905	76,460	79,999
1910	139,122	104,295
1915	55,844	139,229
1923	46,184	101,362

In 1923 there were 2,034,958 short tons of glass sands produced in the United States with a value of $3,751,788. Ohio's contribution to the output for that year was therefore only a little more than 2 per cent in weight and less than that in value.

LOCATION AND QUALITY OF OHIO GLASS SANDS.

Ohio has enormous quantities of sandstone, but as is shown on later pages its composition is not suitable for glass, except for common products where color is not objectionable. Iron is the chief trouble maker. Alumina is always present, but this in itself is not objectionable. In fact some glass makers add alumina, which is said to increase the toughness of glass. Calcium and magnesium oxide also are almost always present, but they do little or no harm if their proportion is fairly constant. However, in one locality in Ohio they range from 6 to 18 per cent of the rock, with of course a corresponding variation in the silica. Titanium oxide also is present, but its proportion is commonly less than one-fourth of one per cent. It, too, gives color and therefore is objectionable except in the most common varieties of glass.

These impurities can be reduced by washing. Thus in 42 samples the content of iron oxide averaged 0.35 per cent and after washing 0.18 per cent, a decrease of 49 per cent. In like manner the titanium oxide was reduced 57 per cent and the alumina 67 per cent. It should be stated that the chemical analyses which form so important a part of this paper were made in the laboratory of Professor D. J. Demorest.

In the following pages the principal deposits of sandstone in the State are reviewed. Those lowest in the geological time scale are first considered, then the next lowest, and so on.

SANDS OF DEVONIAN AGE.

The Monroe limestone forms the surface of several thousand square miles in western Ohio. In Lucas County it consists of three principal divisions:

Detroit River dolomite	*Devonian*	120 feet
Sylvania sandstone		40 feet
Bass Island dolomite	*Silurian*	

Only the Sylvania sandstone concerns us in this paper. It can be traced as a narrow band from the Ohio-Michigan State line south to Otsego Falls of the Maumee. Beyond that its position is below drainage and data concerning it are therefore lacking. While the sandstone has been quarried at several places in Lucas County, the best known deposit is that at Silica, two and one-half miles south of the State line.

Silica.—In 1914 the Owens Bottle Machine Company purchased the plant of the Toledo Silica Sand Co., at Silica, Lucas County. When this quarry was first opened is unknown, but sand was gotten here as early as 1863 and shipped to Pittsburgh, where it was used for making flint glass.* Since that time the rock has been quarried at irregular periods.

When visited in 1917, from 16 to 24 feet of sandstone was being quarried, but the core drill is reported to have shown a maximum thickness of 60 feet.† The beds dip sharply to the west so that the outcrop is narrow. In general the sandstone is poorly cemented with calcite or dolomite and has a light-gray color. The beds range from a few inches to several feet in thickness and are irregular. Bottles and window glass have been the principal products in the glass line.

Chemical Analysis.

	Rock Chips from Quarry Face	Glass Sand Washed
Silica, SiO_2	90.73	95.11
Alumina, Al_2O_3	.76	.13
Ferric oxide	.06	.02
Calcium carbonate, $CaCO_3$	5.00	3.05
Magnesium carbonate, $MgCO_3$	3.18	1.42
Titanium oxide, TiO_2	.00	.00
Loss on ignition	.30	.25

The company reports the silica to range from 88 to 96 per cent and the calcium and magnesium carbonates from 6 to 18 per cent. The iron is low, but the varying proportion of silica and the rapidly changing calcium and magnesium make the sand unsatisfactory. No sand has been used from this quarry for glass making since 1920 and the large and well equipped plant has been dismantled.

*Geol. Survey Ohio, Vol. I, p. 582.

†Prof. J. E. Carman, who has made a detailed study of this region, gives the thickness of the sandstone as 40 feet.

SANDS OF MISSISSIPPIAN AGE.

The Mississippian rocks of Ohio consist of shales, sandstones, conglomerates, and limestone. They outcrop as a broad belt from Ashtabula and Trumbull counties west to the middle of the State and thence due south to the Ohio River, where the rocks cross into Kentucky. The only Mississippian rocks that have been used for glass making lie near the top and include the Black Hand and the Logan formations.

Millwood.—On the south side of the Kokosing River, near the village of Millwood, in the eastern part of Knox County, a sandstone of Mississippian age (probably the Black Hand) has been worked since 1906 for glass and molding sand. The rock which is worked to a depth of 22 feet lies in thin, uneven layers except near the base, where a bed of 3 or 4 feet thick was noted. As a whole, the rock is poorly cemented and hence easily crushed. On the east side of the quarry and part of the south the rock has a light buff color, but on the west side and part of the south it is light gray. The latter is or has been used at Mt. Vernon, Columbus, and Coshocton for glass making, and is now used by the Pittsburgh Plate Glass Co., at Mt. Vernon, for window glass. The buff sand finds a market for steel castings. The sand is also employed in making water glass, and for water filters. Columbus, Lima, Delaware, Struthers, Toronto, and Flint, Michigan, were supplied for the latter purpose. It is claimed that on the north side of the river there is 30 feet of light-colored sand. The operating company is the Knox White Sand Co.

Chips were taken of the gray sandstone from the west end of the quarry and from ledges exposed along the Kokosing, and on analysis gave the following results:

	Chips from West End of Quarry Percent	Chips from Bluffs of Kokosing Percent
Silica, SiO_2	98.60	97.63
Alumina, Al_2O_3	.18	.59
Ferric oxide	.09	.22
Calcium oxide, CaO	.02	.00
Magnesium oxide, MgO	.06	.01
Titanium oxide, TiO_2	.03	.04
Loss on ignition	.21	.70
	99.19	99.19

After laboratory washing the first sample had its ferric oxide reduced to .07 per cent and the second to .14 per cent.

Microscopical examination of the first sample showed the following minerals which are listed in order of their abundance: quartz, kaolin, muscovite, limonite, zircon, sericite, hematite, rutile, and chlorite. In the second sample feldspars are listed in abundance after silica, due probably to less weathering than in the first sample.

Plant of the E. H. Everett Co. This plant is located at Black Hand rock on the Licking River in the eastern part of Licking County. It has been operated since about 1890 and the product goes to the plant of the American Bottle Co., at Newark, where it is used for making bottles for beverage purposes. A section in the quarry is given below:

Mantle rock	4 ft.
Logan formation. Thin-bedded, coarse-grained sandstones. Rejected	21
Black Hand formation. Thick-bedded, coarse-grained sandstone, pebbly in places. Buff colored	60

The sand is crushed, screened, and washed, and then thrown on the stock pile. The iron content varies. In places it is barely sufficient to impart a buff color, but occasionally it forms crusts of siliceous ore. In places thin shale or clay layers are found. No carbonaceous matter was observed. The composition of the sand is shown by the following analyses:

	Unwashed Sand	Washed Sand	Washings
Silica, SiO_2	97.05	98.80	65.80
Alumina, Al_2O_3	1.50	.12	16.60
Ferric oxide	.79	.52	5.71
Calcium oxide, CaO	.00	.00	.42
Magnesium oxide, MgO	.00	.00	.25
Titanium oxide, TiO_2	.18	.10	1.10
Loss on ignition	.40	.22	6.30

The washed sand was examined with a microscope and the following minerals identified. They are listed in order of their abundance: Quartz, orthoclase, plagioclase, microcline, tourmaline, limonite, sericite, kaolinite, magnetite, chlorite, rutile, zircon, and monazite.

When working in full the quarry produces approximately 250 tons per day, but the average is only one-half of that.

Rockbridge.—About 2 miles south from Rockbridge, Hocking County, the Black Hand formation was formerly worked for

glass and molding sand. When visited the quarry face had a maximum height of 60 feet and a length of 250 feet. The rock is coarse grained and has two layers of pebbles, each about 2 feet thick, and lying from 12 to 16 feet apart. At the north end of the quarry one of these thickens to 9 feet. Occasional quartz pebbles were found scattered through the mass of rock. At the top and bottom of the quarry the rock has a buff color, but below the pebbly layers it is light gray. Throughout the mass are spots or patches of darker color, due to concentration of iron.

This rock was crushed in a gyratory crusher and further reduced in a wet pan. It was then run through a revolving wheel screen and an auger washer, and transported to the stock pile for draining. Later it was passed through a drier and screened again.

Three grades of sand were produced. The best was a pure white that was obtained from beneath the pebbles. It was used in making window glass. The second grade was also a glass sand, but less pure than the first. However, much of the second grade was disposed of to steel mills and to brick plants. The third grade had its source in the colored rock and was used for sanding steel rails in coal mines and on traction lines. The pebbles, which are highly objectionable in glass sand, were carefully screened and sold to clean steel and iron castings. Two samples gave the following analyses:

	Pure Glass Sand Washed	Glass Sand Washed
Silica, SiO_2	98.63	98.73
Alumina, Al_2O_3	.44	.45
Ferric oxide	.13	.46
Calcium oxide, CaO	.00	.00
Magnesium oxide, MgO	.03	.00
Titanium oxide, TiO_2	.25	.13
Loss on ignition	.20	.22
	99.68	99.99

Microscopic examination of the first sample showed the presence of the following minerals, which are listed in order of their abundance: Quartz, kaolinite, tourmaline, zircon, limonite, magnetite, apatite, and rutile. In the second sample limonite and hematite rank third and fourth in abundance.

A fire destroyed the plant in 1915 and it was then abandoned.

SANDS OF PENNSYLVANIAN AGE.

Rocks of Pennsylvanian age extend from the Ohio-Pennsylvania line southwest to the Ohio River and cover a large part of the eastern third of the State. They include coal, clay, shale, sandstone, conglomerate, and limestone.

Only the two lower formations, Pottsville and Allegheny, have been sources of glass sand and of these the Pottsville is the more important. The basal member is the Sharon conglomerate, which in places is pebbly and elsewhere a coarse sandstone or even a shale. The rock is massive and poorly cemented.

The pebbles are of quartz and vary in size from a small fraction of an inch to 3 inches or more. The color is of light shades. Near the top, buff is the common color of the rock, but below, where weathering has been less, gray is the usual shade.

The Sharon varies greatly in thickness. Lamb places the maximum in northern Ohio at 90 feet and Stout*that for the southern part of the State at 200 feet. Thicknesses of 50 feet are common. At present this sand is used in a small way for window glass and bottles.

The Allegheny formation has deposits of sandstone, but they are much thinner than the Sharon conglomerate. Nearly everywhere they are high in iron and therefore unsuited for glass except perhaps the most common wares. In Tuscarawas County rock of this age is quarried for steel molding sand.

Hartford.—The plant of the Standard Silica Co. is located one and one-half miles west of Hartford, Trumbull County, on the western margin of a ridge of the Sharon conglomerate. A maximum of 30 feet of the rock was quarried. The upper 6 to 8 feet is decidedly pebbly; below this the rock is a coarse sandstone. The color ranges from buff to gray. Small grains of coal are scattered through the rock.

The rock was loaded on cars with a steam shovel, was crushed, screened, washed, and dried. For several years this sand had a market for the manufacture of glass fruit jars. Other uses were for molding sand and for concrete.

This plant began shipping sand in December, 1910; it was closed in March, 1921. High freight rates are reported to have been the principal reason for closing the works.

*This Journal, Vol. 21, p. 252.

National Sand and Stone Company.—The plant of this company is located in Mahoning County about 2 miles south of Mineral Ridge. The rock is a coarse sandstone, the lower 3 feet in places conglomeratic, and lies at or near the base of the Pennsylvanian. Specks and even small pockets of coal are occasionally found; one was noted which measured 5 inches in thickness. As much as 43 feet of sandstone has been quarried. The top 10 feet is in beds usually less than 12 inches thick, but the rest of the quarry is more massive and beds measuring 10 feet were found. The rock is friable and therefore easily crushed. The upper two-thirds of the stone has a buff or yellow color, and that below gray, the difference being due to weathering. The buff stone is crushed and washed and disposed of for foundry purposes, for brick making, and on traction rails to prevent slipping.

The gray stone is crushed in a jaw crusher, ground in a wet pan, washed, screened, and dried. In washing, 6 tons of water is said to be used for each ton of sand. Glass is the chief use of this product and the market is said to extend from Cleveland to Washington, Pa. The proprietor stated that the General Electric Co. finds this sand satisfactory for making electric light bulbs. It has also been used in making various grades of bottles and window glass. Other uses are for water glass and the white coat for plastering.

Following are analyses of two samples of washed glass sand from this plant:

Silica, SiO_2	99.33	98.31
Alumina, Al_2O_3	.10	.39
Ferric oxide	.009	.31
Calcium oxide, CaO	.07	.09
Magnesium oxide, MgO	.05	.04
Titanium oxide, TiO_2	.09	.08
Loss on ignition	.15	.26
	99.799	99.48

Massillon.—At Massillon, Stark County, is the Everhard quarry, which was opened in 1884. Its main products have been steel molding sand, furnace sand, core sand, building stone, and to a much smaller extent glass sand.

The beds worked are coarse grained, and have a maximum thickness of 60 feet. The rock is friable and shelly near the top, but thicker below. In fact, beds 10 feet thick and without a horizontal break were noted. The color is buff, but in a

quarry a little farther west it is light brown, called pink by the workmen.

Selected chips from the quarry face had the following composition:

	Percent
Silica, SiO_2	96.51
Alumina, Al_2O_3	1.90
Ferric oxide	.58
Calcium oxide, CaO	.07
Magnesium oxide, MgO	.01
Titanium oxide, TiO_2	.12
Loss on ignition	.56
	99.75

A sample collected in the same manner was examined with a microscope and the following minerals noted. They are listed in the order of their abundance: Quartz, limonite, kaolinite, feldspars, muscovite, hematite, sericite, zircon, and magnetite.

DUNDEE SANDSTONE.

The Dundee sandstone lies near the base of the Allegheny formation. It is well exposed along the valley of Sugar Creek in the northwest corner of Tuscarawas County, where it is worked in a large way at Barrs Mills, Dundee, and Beach City for steel molding purposes and furnace bottoms, and to a much smaller extent for glass sand. The rock is coarse grained, but is without pebbles, and has a color which ranges from gray to buff, the latter predominating. Fifty feet or more of the rock is quarried.

The composition of the sand along Sugar Creek Valley is shown below:

	Massillon Sand & Stone Co. Unwashed Barrs Mills	National Malleable Castings Co. Unwashed Dundee	Beach City Silica Sand Co. Unwashed
Silica, SiO_2	98.28	96.63	97.76
Alumina, Al_2O_3	.32	2.00	.69
Ferric oxide	.24	.42	.34
Calcium oxide, CaO	.00	.00	.00
Magnesium oxide, MgO	.13	.04	.11
Titanium oxide, TiO_2	.07	.20	.05
Loss on ignition	.32	.60	.40

A sample of the stone from Barrs Mills was examined with the microscope, and the following minerals noted. In order of their abundance they are, quartz, microcline, feldspars, limonite, kaolinite, tourmaline, chlorite, zircon, titanite, and serpentine.

Barberton.—The plant of the Summit Silica Co. is located near the southern border of Barberton, Summit County, where a ledge of the Sharon conglomerate, 45 feet high, is the basis of the industry. In places the pebbles are confined to part of the ledge, while elsewhere they occur through the mass. The company estimates that 60 per cent of the rock is pebbly. Most of the pebbles are less than one inch in diameter and the largest observed measured about 3 inches. They are of quartz and have various shades of light colors.

The rock is crushed and washed, and that used for glass making is dried and screened. However, only the sandy part of the rock is marketed for glass making. In other words, the crushed pebbles are not used for that purpose. The sand is suitable for window glass, bottles, and in fact any kind of glass except the higher grades.

Following is an analysis of a sand from this plant:

	Unwashed and Unscreened Sand. Percent.
Silica, SiO_2	97.41
Alumina, Al_2O_3	.58
Ferric oxide	.31
Calcium oxide, CaO	.11
Magnesium oxide, MgO	.00
Titanium oxide, TiO_2	.09
Sodium oxide, Na_2O	.04
Potassium oxide, K_2O	.08
Loss on ignition	.44
	99.06

Microscopical examination of the first sample showed the following minerals which are listed in order of their abundance: Quartz, magnetite, zircon, kaolinite, feldspar, muscovite, and apatite.

Chalfants.—The Chalfants plant of the Central Silica Co. is situated in the northern part of Perry County, and has been in existence for more than 40 years. The rock worked is the Pottsville conglomerate, and is covered with from 4 to 6 feet of stripping, which is removed with a drag line system. Beneath the stripping the stone is worked to a depth of 35 feet. It is coarse-grained sandstone and in places contains quartz pebbles. Near the top the rock is shelly; farther down the layers are thicker; while near the base of the quarry the rock is massive. The material is poorly cemented and its color varies from buff to light brown. The rock is loaded onto cars with a steam shovel, and is hauled to the mill by a dinky engine.

The rock is broken in a gyratory crusher and is further reduced in a dry pan. It is then run through a 6-mesh rotary screen and the material which passes through it is washed and dried. Again this sand is screened, first through a 20-mesh and then through a 16-mesh. What passes through the latter is disposed of in large part for green and amber bottles and for window glass. When the plant is working to capacity this amounts to 80 tons per day or about 48 per cent of the output.

Jackson County.—Sandstone was formerly quarried on the J. S. McKitterick farm, one mile north of Jackson, for bottle glass, but when the plant at Jackson was closed the one market for this glass sand was at an end.

The sandstone, of which a ledge of 60 feet is exposed, lies on or near the horizon of the No. 1 coal. It is coarse grained and poorly cemented. The color varies from gray to brown. No mill was erected, the rock being crushed with hammers by hand labor.

The Ohio Flint and Glass Sand Co.—The quarry of this company is located on the Jasper Middaugh farm in the southwest corner of Section 25, Reading Township, Perry County. The rock lies at an elevation of about 1,080 feet and while its position in the rock column has not been accurately determined, it appears to lie in the Allegheny formation, or lower coal measures.

The sandstone which is covered with about 2 feet of mantle rock has been quarried to a depth of 18 feet, and it is reported that the drill showed 14 feet of sandstone below this. Near the top the rock is thin-bedded, but the layers increase in thickness below. The sandstone is coarse grained and poorly cemented. White mica or muscovite is common. The color varies from light gray to buff. Other knobs in this locality carry the sandstone.

Analyses.

	Washed Sand	Chips from Quarry Face
Silica, SiO_2	98.01	94.23
Iron oxide, Fe_2O_3	.29	.34
Alumina, Al_2O_3	.35	2.98
Titanium oxide, TiO_2	.20	.28
Phosphorus pentoxide, P_2O_5	.02	.02
Calcium oxide, CaO	.14	.20
Magnesium oxide, MgO	.34	.22
Sodium oxide, Na_2O	.16	.11
Potassium oxide, K_2O	.24	.86
Ignition loss	.45	1.00

The rock is trucked to Rushville Station, where it is crushed, screened, washed, and dried. It is claimed that in washing the sand loses much of its color. For some months the plant is idle because the roads are such that trucking can not be done. At present (1924) the company is considering the erection of an aerial tramway from quarry to mill. The sand has been used by the Hazel Atlas Glass Co., at Zanesville.

COMPOSITION OF OHIO SANDS.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Athens County							
Palos (Mahoning sandstone, Conemaugh formation)							
Chips from fresh surface	89.88	6.01	.82	.00	.12	.12	1.12
Carroll County							
Craig Stone Co. (Conemaugh formation)							
Chips from fresh surface	94.91	2.80	.54	.00	.04	.15	.90
Prosperity Quarry (Conemaugh formation)							
Chips from fresh surface	95.92	2.31	.36	.00	.05	.12	.90
Columbiana County							
Jessup Quarry, Salem (Allegheny formation)							
Rock crushed but unwashed	85.14	6.08	3.66	.10	.13	.25	2.65
O'Mara Quarry, Lisbon. (Allegheny formation)							
Chips from rock face	94.30	2.97	.58	.00	.15	.15	1.10
Coshocton County							
Chips from ledge near Chili (Allegheny formation)	96.24	.....	.45	.00	.04	.....	.58
Layland Sand & Stone Co. (Pottsville formation)							
Chips from quarry face	95.20	2.30	.45	.00	.10	.10	.69
Moore Quarry, Warsaw (Pottsville formation)							
Chips from quarry face	92.66	3.92	.50	.00	.01	.15	.70
Cuyahoga County							
Berea sandstone at Berea							
Chips of rock and sand from grindstone plant	91.78	4.12	.84	.11	.04	.24	1.19
Berea sandstone, Berea	93.13	3.86	.65	.19	.25	.....	1.43

COMPOSITION OF OHIO SANDS—CONTINUED.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Fairfield County							
Allegheny Quarry, 4 miles east of Lancaster (Black Hand and Logan formations)							
Chips from fresh surface of quarry.....	96.03	1.34	.92	.00	.13	.25	.55
Sharp Quarry, Sugar Grove (Black Hand formation)							
Clean chips from spalls.....	97.43	.51	.58	.00	.10	.09	.41
Gallia County							
Fitzpatrick farm, near Alice (Conemaugh formation)							
Chips from face of ledge, unwashed....	93.07	3.71	.42	.02	.03	.12	.80
Same, but washed.....	95.43	1.85	.37	.00	.03	.12	.40
Harrison County							
Ozark Quarry (Conemaugh formation)							
Chips from quarry face.....	93.56	4.04	.60	.00	.03	.13	1.15
Hocking County							
Rockbridge Quarry of Central Silica Co. (Black Hand formation)							
Glass sand, washed.....	98.63	.44	.13	.00	.03	.25	.20
Glass sand, washed.....	98.73	.45	.46	.00	.00	.13	.22
Holmes County							
Uhl Quarry, near Killbuck (Pottsville formation)							
Purest rock.....	97.41	.65	.12	.12	.00	.07	.27
White rock.....	97.06	1.30	.15	.01	.06	.15	.25
Less pure rock.....	96.48	1.44	.20	.00	.04	.13	.30
Glenmont Quarry (Pottsville formation)							
Chips from quarry face.....	95.24	2.55	.38	.07	.00	.28	.43
Columbus Co. Quarry (Pottsville formation)							
Chips from quarry face.....	96.30	1.88	.42	.00	.03	.12	.60
Gray Quarry near Hardy's Switch. (Pottsville formation)							
Chips from quarry face.....	94.25	3.17	.63	.01	.06	.15	.61
Jefferson County							
Quarry on Champion and Duffy farms (Conemaugh formation)							
Chips from quarry face.....	84.42	8.08	2.50	.04	.01	.51	2.10
Knox County							
Millwood White Sand Co. (Logan (?) sandstone)							
Glass sand, unwashed.....	98.60	.18	.09	.02	.06	.03	.21
Molding sand, washed.....	98.29	.15	.28	.03	.06	.03	.23
Chips from ledges along the Kokosing	97.63	.59	.22	.00	.01	.04	.70

COMPOSITION OF OHIO SANDS—CONTINUED.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Jackson County							
Jackson Sand Mining Co., 2 miles north of Coalton. (Pottsville formation)							
Bin sample, top sand, unwashed	96.79	2.00	.20	.00	.08	.17	.55
Bin sample, bottom sand, unwashed	96.19	2.22	.20	.00	.03	.18	.65
Chips from near-by ledges	98.50	.70	.22	.10	.00	.10	.35
Buzzard Rocks cliff							
Chips from quarry face	98.60	.45	.37	.10	.00	.05	.30
Lawrence County							
Wallenfelsz and Williams farm, north of Ironton, (Pottsville formation)							
Chips from quarry face	91.09	4.80	1.10	.00	.10	.15	.92
Petersburg Fire Brick & Tile Co., Coal Grove. (Allegheny formation)							
Chips of fire stone	85.57	9.06	.42	.02	.03	.34	2.10
Chips of ganister	92.35	4.51	.63	.00	.07	.45	1.13
Licking County							
Everett Quarry, Toboso (Black Hand formation)							
Glass sand, unwashed	97.05	1.50	.79	.00	.00	.18	.40
Glass sand, unwashed	97.11	1.47	.72	.00	.02	.18	.40
Glass sand, washed	98.80	.12	.52	.00	.00	.10	.22
Washings	65.80	16.60	5.71	.42	.25	1.10	6.30
Lorain County							
Cleveland Stone Co. Quarry. South Amherst (Berea sandstone)	92.15	3.85	1.40	.50	.20	.40	1.70
Lucas County							
Toledo Silica Sand Co. (Monroe formation)							
Rock chips from north end of quarry	90.73	.76	.06	5.00	3.18	.00	.30
Car sample of sand. Washed and screened	95.11	.13	.02	3.05	1.42	.00	.25
Mahoning County							
Spencer Quarry, 2 miles south of Ellsworth (Pottsville or Allegheny formation)							
Chips from quarry face	98.14	.45	.13	.04	.02	.09	.35
National Sand & Stone Co., 2 miles south of Mineral Ridge. (Pottsville formation)							
Best glass sand, washed	99.33	.10	.009	.07	.05	.09	.15
Glass sand	98.31	.39	.31	.09	.04	.08	.26

COMPOSITION OF OHIO SANDS—CONTINUED.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Perry County							
Chalfant Quarry of Central Silica Co. (Pottsville formation)							
Glass sand, washed	99.43	.18	.13	.00	.05	.04	.22
Steel sand, washed	95.66	1.84	.19	.00	.16	.22	.87
Ganister, unwashed	98.61	.39	.20	.00	.06	.20	.27
Blast sand, washed	97.99	1.08	.22	.00	.07	.08	.53
Washed sand from pit of Ohio Flint & Glass Sand Co., Reading Township. (Allegheny (?) formation)	98.01	.35	.29	.14	.34	.20	.45
Chips of sandstone from face of same quarry	94.23	2.98	.34	.20	.22	.28	1.00
Pike County							
Berea sandstone, near Waverly	91.00	5.20	1.47	tr.	.28	.....	1.80
Portage County							
Kent Quarry (Pottsville formation)							
Chips from old quarry face	98.56	.28	.10	.08	.02	.07	.40
Portage Silica Co. (Pottsville formation)							
Steel molding sand, washed	98.14	.16	.35	.38	.05	.08	.31
Fine blast sand, washed	98.46	.17	.23	.17	.00	.03	.28
Coarse blast sand, washed	98.04	.24	.28	.21	.01	.03	.30
Very fine washings	92.15	3.19	.72	.76	.06	.65	.40
Stark County							
Coxey Silica Sand Co., Pauls. (Pottsville formation)							
White steel molding sand, unwashed	96.87	1.58	.13	.00	.03	.17	.57
Buff steel molding sand, unwashed	95.67	1.95	.53	.12	.00	.15	.64
Sonnhalter Sand & Stone Co., Massillon. (Pottsville formation)							
Glass sand, washed	96.77	.84	.61	.02	.17	.20	.52
Rolling mill sand, unwashed	93.63	3.50	.80	.04	.00	.23	1.25
Massillon Silica Sand Co. (Pottsville formation)							
Finer steel molding sand, unwashed	97.40	1.44	.49	.11	.02	.13	.52
Coarser steel molding sand, unwashed	97.48	.56	.32	.05	.04	.07	.50
Everhard Co., Massillon. (Pottsville formation)							
Bottle glass or steel molding sand	95.75	1.60	.81	.00	.02	.15	.68
Furnace bottom sand	96.29	1.63	.33	.03	.00	.20	.43
Scioto County							
Damarin Hill Quarry, Portsmouth. (Pottsville formation)							
Chips from face of quarry	97.49	1.59	.28	.00	.07	.15	.51
McDermott Quarry, (Cuyahoga formation)							
Blue-gray stone	85.60	7.25	2.60	tr.	tr.	.75	1.70
Yellow stone	84.50	6.35	3.00	tr.	tr.	.75	2.15

COMPOSITION OF OHIO SANDS—CONTINUED.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Summit County							
Summit Silica Co., Barberton, (Pottsville formation)							
Sand, unscreened and unwashed	97.41	.58	.31	.11	.00	.09	.44
Emery Sand Plant, Twinsburg. (Pottsville formation)							
Sand, unwashed	97.74	.46	.83	.00	.18	.09	.34
Akron White Sand Co., Akron. (Pottsville formation)							
Sand, unwashed	97.10	1.27	.19	.00	.05	.08	.55
Newell Quarry, Macedonia. (Pottsville formation)							
Chips from lower half of quarry	98.00	.36	.53	.01	.08	.....	.34
Chips from lower half of quarry	98.29	.69	.18	.00	.00	.04	.28
Bramley Quarry, Copley (Pottsville formation)							
Chips from quarry face	98.54	.28	.24	.01	.01	.07	.29
Boston ledges, Boston Township. (Pottsville formation).							
Chips from 50-foot face	97.91	.51	.44	.05	.06	.05	.32
Erie Railroad cut, 2½ miles west of Barberton. (Pottsville formation)							
Chips from face of ledge	96.07	2.91	.19	.14	.06	.18	.46
Trumbull County							
Trumbull Stone & Sand Co., 5 miles west of Warren. (Pottsville formation)							
Selected furnace sand, unwashed	97.13	1.52	.27	.01	.03	.23	.39
Furnace sand, unwashed	95.99	1.97	.35	.09	.00	.27	.62
Tuscarawas County							
American Sand Co., 1 mile north of Dundee (Pottsville formation)							
Selected steel molding sand, unwashed	97.99	.....	.45	.00	.05	.....	.43
Steel molding sand, unwashed	96.00	2.08	.31	.02	.03	.18	.61
National Malleable Castings Co., Dundee. (Pottsville formation)							
Core sand, unwashed	96.10	1.91	.33	.00	.02	.26	.67
Steel molding sand, unwashed	96.63	2.00	.42	.00	.04	.20	.60
Beach City Silica Sand Co., (Pottsville formation)							
Steel molding sand from bottom rock	97.76	.69	.34	.00	.11	.05	.40
Steel molding sand from top rock	97.95	1.00	.37	.00	.06	.12	.35
Dundee Silica Sand Co., Dundee. (Pottsville formation)							
Furnace bottom sand, unwashed	94.30	2.85	.86	.00	.04	.33	.80
Coarse steel molding sand from bottom of quarry	98.76	.25	.19	.00	.04	.04	.40
Selected steel molding sand	97.40	1.13	.13	.00	.02	.17	.30

COMPOSITION OF OHIO SANDS—CONTINUED.

	Silica, SiO_2	Alumina, Al_2O_3	Ferric Oxide	Calcium Oxide, CaO	Magnesium Oxide, MgO	Titanium Oxide, TiO_2	Loss on Ignition
Tuscarawas County—(Continued)							
White Rock Silica Sand Co. (Allegheny formation)							
Furnace bottom sand, unwashed	96.87	1.20	.45	.00	.06	.11	.43
Steel molding sand, unwashed	96.52	1.83	.31	.00	.03	.17	.39
Massillon Silica Sand Co., Barrs Mills. (Pottsville formation)							
Steel molding sand, unwashed	98.28	.32	.24	.00	.13	.07	.32
George J. Miller farm, 1½ miles southwest of Newcomerstown. (Allegheny formation)							
Fresh chips from outcrop	92.55	.....	....	.03	.01	.....	1.15
Vinton County							
Beckley farm, 1½ miles south of McArthur							
Fresh chips from outcrop	94.03	3.24	.40	.00	.08	.13	.76
Wayne County							
Oliver Silica Sand Co., Warwick. (Pottsville formation)							
Steel molding sand, unwashed	98.30	.89	.27	.02	.05	.07	.32
Franklin Industrial Co., Warwick. (Pottsville formation)							
Steel molding sand, unwashed	97.47	.72	.38	.00	.06	.09	.60

TYPE AND VENATION OF WINGS AS FACTORS IN SEPARATING CERTAIN DELTOCEPHALOID GENERA.

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A few of the *Deltocephaloid* genera of the *Cicadellidæ* such as *Deltocephalus*, *Lonatura* and *Aconura** (American forms) are so closely related that specialists working upon this group are puzzled frequently to know just how to separate the species concerned by constant generic characters. Although as in many other groups, the generic standing of certain species is quite easy to determine, other species exhibit characters more common to allied genera. While the writer was engaged in a monographic study of the species of *Deltocephalus*, the question was asked by several co-workers where the line should be drawn between these genera or what character should be used as a final criterion for separation. These genera were therefore given special study from a comparative standpoint and an examination was made of all available material in them. This study has revealed several characters, some of a detailed technical nature. The most conspicuous and outstanding one, however, has to do with wing characters or conditions. These types of wings seem to indicate on the one hand definite relationships among certain species and on the other hand exhibit structural differences between these genera which form a basis for their separation. These genera however, which in the writer's opinion should be considered as generic groups, at least in the making, have apparently not yet diverged sufficiently that hard and fast lines can be drawn to separate them. There is consequently some doubt regarding the generic standing of a few species.

Throughout these genera it is common for many or all species belonging to a genus to have a dimorphic condition in the first pair of wings or elytra. In *Deltocephalus* this condition is lacking in certain subgroups and only the normal wing condition is known; but it is found in all described species of certain

* The genus is considered here as given by Van Duzee in his catalogue of Homoptera, 1916. The true *Aconura* species probably do not occur in North America.

other groups. The short winged condition is usually spoken of as a brachypterous wing and the long winged, the macropterous form. All of these species feed upon grasses and the great majority of those containing short winged forms are plains and prairie species. The size of the wing in these species may be of very slight importance so far as their ability to survive is concerned, since very little or no extended locomotion may be necessary in such a habitat.

With reference to this dimorphic wing condition in *Deltocephalus*, one of the most interesting discoveries during this study was the capturing of a male of *D. mendosus* Ball on a prairie adjoining a Florida everglade. This specimen has a right elytron of the macropterous variety and the left wing is a brachypterous form. A photograph of this specimen is inserted in the accompanying plate. Perhaps this might be called a heteromorph. It can scarcely be termed a gynandromorph of the lateral type for all other structures except the wings are normal, especially the genital structures of the male which are typical and normal for that sex and species. It would certainly be necessary to have both sexual structures represented to classify it thus.

In this specimen each of the elytra is typical of the form it represents. That is, in an examination of several hundred specimens of *D. mendosus* and a comparison with this specimen in question, it is found that the right elytron is typical of macropterous individuals and the left elytron is typical of the brachypterous specimens. It is therefore merely this dimorphic wing condition exhibited in a single individual. This example is given as it illustrates the condition of the reduction of the wing in the brachpyterous individuals, as this condition occurs throughout the genus *Deltocephalus*. In some species of this genus the elytra are shortened more proportionately, but in all cases each part of the elytron seems to be shortened in proportion to every other part and the cells are merely reduced in size leaving the venation relatively the same.

The greatest reduction probably occurs in the apical portion but in all the material examined consisting of practically all the species of *Deltocephalus* and hundreds of specimens, when reduction occurs there is still a group of apical cells in the brachypterous wing although small in some cases. In an extreme condition of a short winged example of *D. collinus* the outer anteapical and apical cells are combined but this is not typical of

a large series of short winged forms of this species. Even in this extreme case the apical cells are all present with one exception.

In some species of the genus the wing venation will vary in minor respects and is somewhat irregular even in elytra of the same form—brachypterous or macropterous. Especially is this the case where it may be a question of the number of cross veins or the division of certain cells. Even in these instances there is no marked change in the plan or pattern of venation when reduction occurs. A comparison of the right and left elytra in the photograph of *D. mendosus* (Figure 1) will show that the venation in the two elytra is practically the same, except for size, vein for vein and cell for cell. This is the type of wing reduction which is characteristic and almost constant for the species of *Deltocephalus*. Another example shown in Figures 5 and 6 illustrates the long and short winged forms of *D. caperatus* Ball.

In both *Lonatura* and *Aconura* there is also a dimorphic condition of the elytra. As compared with *Deltocephalus* the type of venation in the short winged condition is somewhat different. As a rule the wings of brachypterous specimens of these genera are much shorter than corresponding wings of specimens of *Deltocephalus*. When thus shortened they cover only the basal two or three segments of the abdomen. From the generic standpoint the character of the wing is probably more important than relative size, although in many specific instances in dealing with these species the length alone has apparently been considered. In both of these genera the short winged condition is produced by an entire loss of the apical portion, or abrupt "cutting off" of the elytron in such a way that the venation of only the anterior portion of the wing occurs in brachypterous forms. There seems to be only a slight tendency, if any, for a comparative shortening of the whole elytron when reduced which would cause the cross veins to appear to be pushed forward and cells in the apical portion of the macropterous wings to be shortened.

In *Lonatura* the condition is somewhat intermediate between the other two, but here it is apparently only the reduction of the wing at approximately the apex of the clavus so that more cells are included in the brachypterous wing as compared with *Aconura* and slightly less of the posterior portion is omitted.

As a rule in *Lonatura* no apical cells are found when reduction occurs and frequently all or part of the anteapical cells are missing. In a few cases like *nebulosa* and *megalopa* formerly

designated as species of *Lonatura* small apical portions are found inside the wing margin. These species however have been placed with their close relatives in the genus *Deltocephalus* and show only a slight remnant of the apical cells.

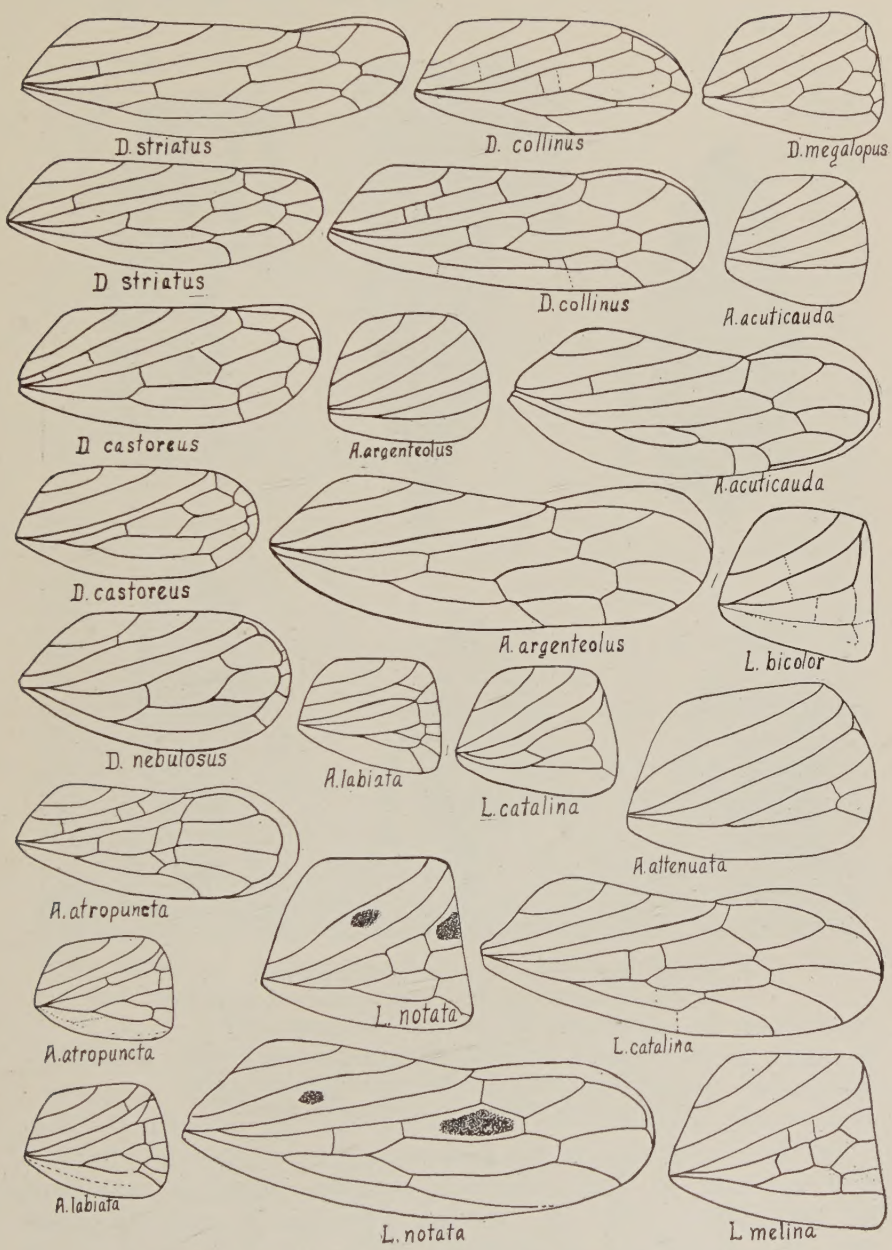
In *Aconura* the wing reduction is even greater and so pronounced in the majority of brachypterous wings that not even a cross vein occurs to separate the elytron into cells. Also the elytron is unusually shortened, the apical margin occurring anterior to the original terminal point of the claval vein. Large numbers of specimens and all the species of *Aconura* have been examined and in no case do apical cells occur in the brachypterous wings. In species like *atropuncta* and *labiata* a few small cells comparable to anteapicals occur at the posterior margin of the wing. But these are so distinct in many respects that they probably should not be placed in the same genus with those designated here as *Aconura*. These brachypterous wings illustrate a somewhat different condition in the wing reduction than do others previously mentioned.

The macropterous form is not known except in a few species of *Aconura*, and certain species of *Lonatura* like *bicolor* are not known to possess long winged forms, although several hundred specimens of a single species have been examined.

In regard to venation proper, the normal and apparently constant condition in the *Deltocephalus* wing is a series of three anteapical cells, with a costal cell beyond the outer anteapical cell. In *Lonatura* there are only two anteapical cells in the long winged forms (*notata*, Plate I) and what is comparable to an outer anteapical extends to the posterior portion of the costal wing margin so that the anteapical and apical cells are combined and the costal cell is apparently wanting. In the genus *Aconura* there seem to be only two anteapicals with the costal cell the same as in *Deltocephalus*. Four apicals are thus formed as in *Deltocephalus* while only three are usually present in *Lonatura*. A few species of *Aconura* as for example *atropuncta* have macropterous wings in which a marginal vein extends from the posterior costal portion to the apex of the clavus. This is comparable to an appendix in other forms but is unique and, combined with other characters, probably represents a distinct genus as previously mentioned.

The wing condition in *Lonatura* and *Aconura* may be only another step in advance of *Deltocephalus* in the process of wing reduction, but as shown in the previous discussion and figures

both the venation and the type of reduction in the elytra indicate generic affinities. This should not be used as an absolute character for determining the generic standing of a species but probably should be emphasized as an important and primary generic character. Investigators who have made a study of the species in these groups have found that the type of genitalia is a very helpful character in attempting to place doubtful species. Many small groups are found whose species are closely related and whose genital structures are very similar. In a few cases these structures are undoubtedly the best to show relationships. Thus the type of wing serves as probably the best although not the final or only criterion for the separation of these genera.


D. striatus
D. collinus
D. megalopus
D striatus
D. collinus
A. acuticauda
D. castoreus
A. argenteolus
A. acuticauda
D. castoreus
A. argenteolus
L. bicolor
D. nebulosus
A. labiata
L. catalina
A. atropuncta
A. attenuata
A. atropuncta
L. notata
L. catalina
A. labiata
L. notata
L. melina

1. Deltocephalus mendosus Ball (heteromorph).
2. Aconeura acuticauda Baker (brachypterous form).
3. Lonatura notata Osborn (macropterous form).
4. Deltocephalus caperatus Ball (macropterous form).
5. Deltocephalus caperatus Ball (brachypterous form).
6. Lonatura notata Osborn (brachypterous form).

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